DoD Space S&T
Community of Interest
Presentation to National Defense University
30 September 2015

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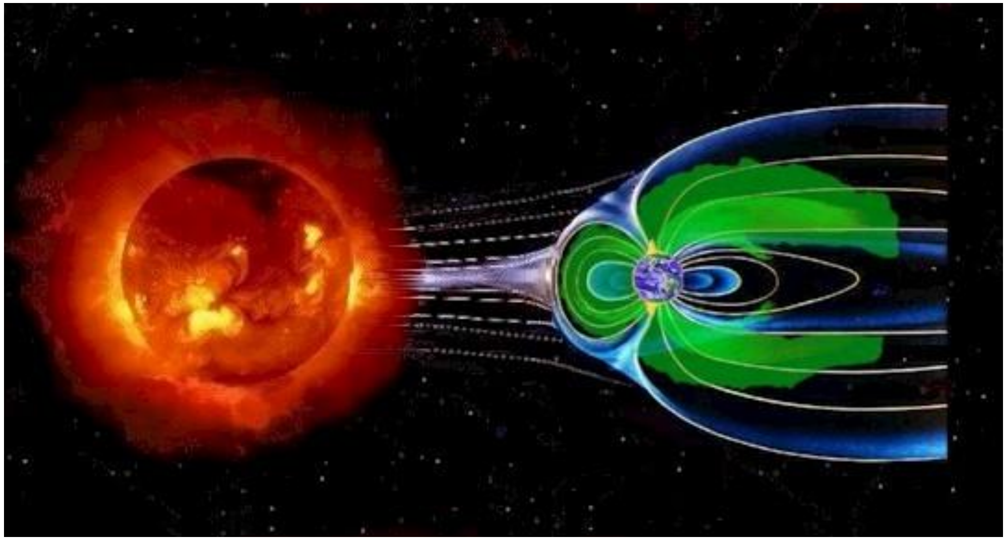
Space Is Unique



- Space is an operating environment; not a technology area
- Space supports all aspects of the Joint Engagement Sequence (JES)
- Space has no “repair shop”
- Space asset behavior is predictable
- Multiple threats – natural, man-made, and adversary

Military Space Enables all Facets of DoD Operations

DoD Space S&T Strategy

- Biennial report to Congress – updated 2015
- Guides the development of the space-unique technologies that are essential to maintain existing U.S. conventional and asymmetric military advantages enabled by space systems at the strategic, operational, and tactical levels
- Looks across the entire DoD Space S&T Enterprise
- Prepared with the assistance of the DoD Space S&T Community of Interest

Space is no longer uncontested

Space Threats

Threat
RF Jamming
Low power laser dazzling
High Power Laser Kill
LEO ASAT
GEO ASAT
On-Orbit Jammers
Co-orbital kinetic ASAT
Adversary attachment
Cyber attack
Space nuclear detonation

Capabilities needed to deliver the Threats

Capability
Ground surveillance networks
World-wide ground SSA coverage
Precision Tracking capability

- In last 5 years, potential adversary threat capability has sharply increased.
- National Space Policy (2010): We will protect our Space Capability from adversary hostile actions.

Space S&T COI Portfolio Overview

- **COI Description**
  - The goal of the Space COI is to 1) Facilitate collaboration and leveraging of complementary investments of the space S&T efforts across the community in support of the intent of the nation's Space interests; and 2.) Identify gaps, establish and maintain a set of S&T roadmaps to guide Space Community research program investments, perform portfolio assessments, and provide future resource recommendations to leadership
- **COI Purpose**
  - The Space S&T COI is a forum for sharing new ideas, technical directions and technology opportunities, jointly planning programs, measuring technical progress, and exchanging advances in space S&T
- **Portfolio Focus**
  - DoD S&T investments in space-unique technologies that are essential to maintain and advance existing U.S. conventional and asymmetric military advantages enabled by space systems at the strategic, operational, and tactical levels

COI Taxonomy

Technology Sub-Area 1
Satellite Communications
Technology Sub-Area 2
Missile Warning, Missile Defense, Kill Assessment and Attack Assessment
Technology Sub-Area 3
Positioning, Navigation and Timing
Technology Sub-Area 4
Intelligence, Surveillance and Reconnaissance
Technology Sub-Area 5
Space Control and Space Situational Awareness
Technology Sub-Area 6
Space Access
Technology Sub-Area 7
Space and Terrestrial Environmental Monitoring
Technology Sub-Area 8
Command and Control; and Satellite Operations
Technology Sub-Area 9
Space Enablers
Technology Sub-Area 10
Space Resilience
(new subarea in FY15)

Space COI Sub-Areas
1 of 2

Satellite Communications
- Provide seamless, end-to-end, space-based communications that is integrated and interoperable
- Technical Challenges
- Reduce SWaP-C and improve thermal management
- Develop V/W band RF and laser comms

Missile Warning, Missile Defense, and Attack Assessment
- Provide timely and unambiguous detection of ballistic missile launches and nuclear detonations from space
- Technical Challenges
- Improved sensors for whole Earth staring
- Improved data fusion algorithms

Positioning, Navigation and Timing
- Generating and using signals to enable determination of precise location, movement, and time
- Technical Challenges
- Improved anti-jam capability
- Improved atomic clocks
- Enhanced orbital navigation technology

Intelligence Surveillance and Reconnaissance
- Space-based systems for SSA and GEOINT& SIGINT; National Technical Means, Commercial/Foreign Family of Systems, and small, rapid-response opportunities
- Technical Challenges
- Increased persistence of ISR
- Improved data compression
- Integrated space, air, ground based ISR integration

Space Control and Space Situational Awareness
- Provide freedom of action in space to ensure: resilience to threats, ability to perform in degraded environment, and deny the adversary's use of space against our forces in conflict
- Technical Challenges
- Improved space object detection and monitoring of potential threats

Space Access
Provide delivery, maneuvering, and recovery of payloads to and from space in a responsive, reliable, flexible manner, ensuring assured access to space in peace, crisis, and through the spectrum of conflict
- Technical Challenges
- Reduce cost and time cycle
- Higher performance on-orbit propulsion
- Enable fully reusable launch systems

Space COI Sub-Areas
2 of 2

Space and Terrestrial Environmental Monitoring

- Provide remote sensing and monitoring of the operational Space environment and Earth weathercasting
- Technical Challenges
- Improved awareness of Earth/Sun environment
- Enable real-time threat warning due to weather
- Enable marine Meteorology and ocean conditions

Command and Control; and Satellite Operations

- Provides the ability to operate over space forces and resources to monitor, assess, plan, and execute space operations at all echelons of command
- Technical Challenges
- Increased autonomy to reduce manning
- Space robotic capabilities for servicing/repair

Space Enablers

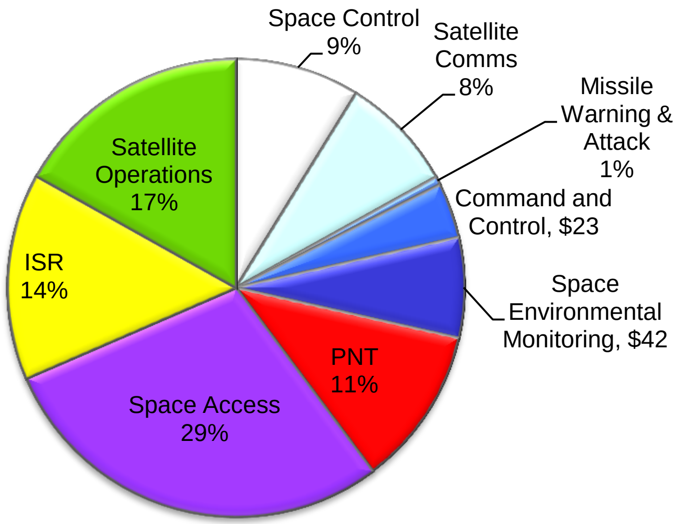
- Development of pervasive technologies that facilitates the technical ability to perform successfully in the Space Arena
- Technical Challenges
- Standardized and miniature components and interfaces
- Carbon-based nanotechnology
- Ultra-high efficiency power systems

Space Resilience

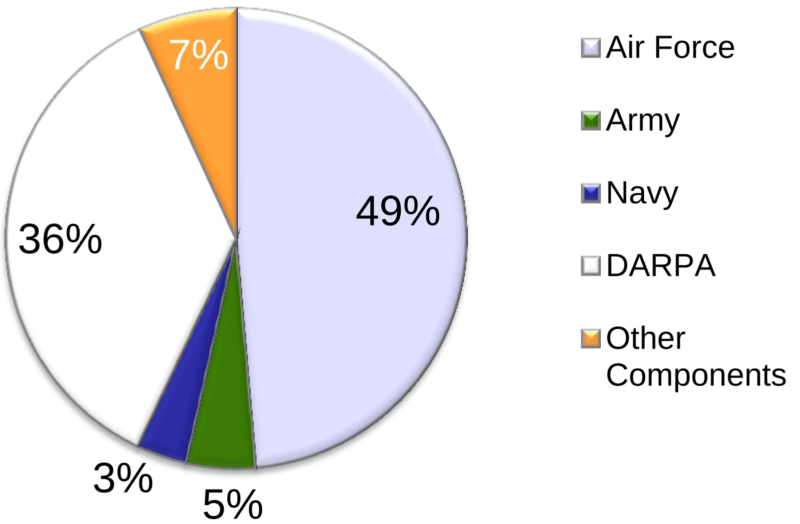
- Provide the ability to support the functions necessary for mission success in spite of hostile action or adverse conditions
- **Technical Challenges**
- On-board adaptive planning
- Local area imaging sensors
- Laser survivability

Space S&T COI Investment and Performers

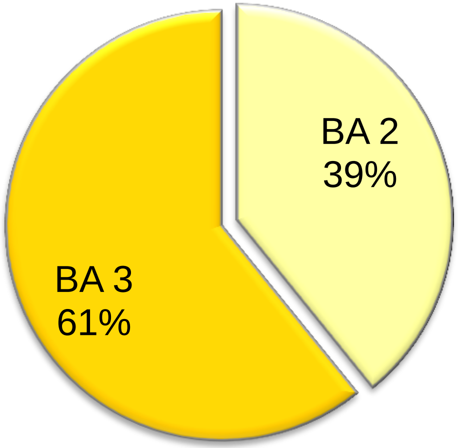
COI Sub-Areas PB16



Component Investment



Budget Activity



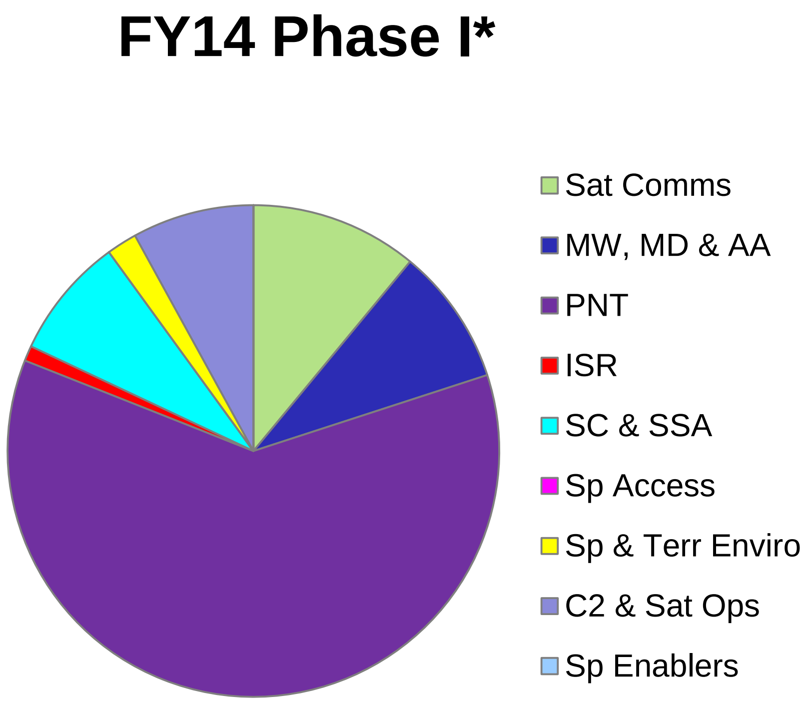
Intramural vs. Extramural split:

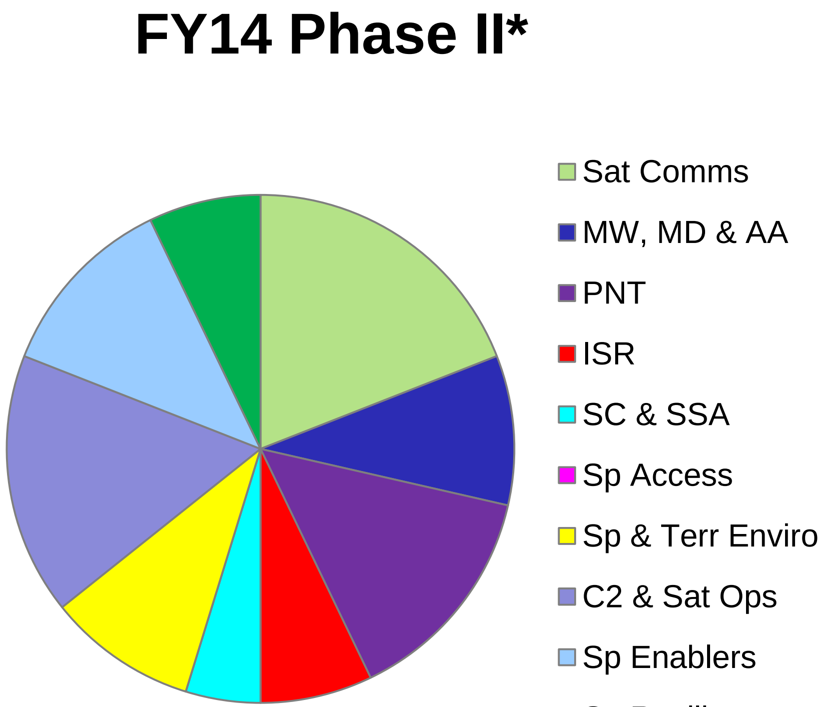
- **Army - 6.2 47/53; 6.3 38/62**
- **Navy - 6.2 60/40; 6.3 40/60**
- **Air Force - 6.2 48/52; 6.3 20/80**

Major Performers:

- **Aerojet-Rocketdyne, APL, BAE Systems, Ball Aerospace, Boeing, Dynetics, Honeywell, Lockheed Martin, MIT-LL, Northrop Grumman, NRL, Orbital/ATK, Raytheon, Sandia National Laboratory, Teledyne Brown**

SBIR Investment
FY14 Phase I and II Awards





100 Awards

42 Awards

*SBIR Phase I (project feasibility) awards normally do not exceed $150,000 total costs for 6 months.

*SBIR Phase II (project development to prototype) awards normally do not exceed $1,000,000 total costs for 2 years.

Space COI
Relationship to Kill Chain

FIND

FIX

TRACK

TARGET

ENGAGE

ASSESS

Satellite Communications

Missile Warning, Missile Defense, Kill Assessment and Attack Assessment

Positioning, Navigation and Timing

Intelligence, Surveillance and Reconnaissance

Space Control

Space Situational Awareness

Space Access

Space and Terrestrial Environmental Monitoring

Command and Control; and Satellite Operations

Space Enablers

Space Resilience

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Space Control

Space Situational Awareness

Gaps

- **Understanding Allied Investments**
  - NATO countries
  - Long-term Allies & partners
  - Other cooperating nations
- **Understanding Investments of Potential Rivals**
  - Intent, Doctrine, ROEs & TTPs
  - Technical performance of systems
- **Understanding Benefits and Risks of Employing Commercial Systems**
  - Security, availability, responsiveness
  - Cost, limitations
- **On-Orbit Servicing & Repair**
  - DARPA Orbital Express – what’s next?
- **Trade-off: Cost v Schedule v Lifetime**
  - 10+ year on-orbit lifetime = high first cost but long replenishment schedule
  - Other paradigm – short life = low initial cost but short replenishment schedule
  - Which paradigm is the future?

Current Challenges Driving Space S&T Investments

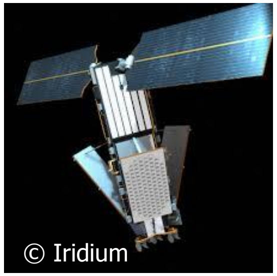
- **Cost-effective manufacturing and acquisition of spacecraft**
  - Very few spacecraft (~3/year) – custom built vs. production line
  - Requirement is for highly specialized payloads – multi-year development required
- **Lower launch cost**
  - Reducing overall launch cycle time – traditional queues can be 2+ years or more
- **Adding protection and resiliency to our current space fleet**
  - Avoiding expensive block upgrades
- **Low data rate comms to dispersed units**
- **Cost-effective sustainment of existing constellations**
  - Budgets declining across the department
- **Improve Ability to forecast terrestrial and space weather**

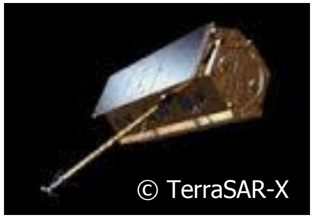
Risks for Space S&T
Public vs. Protected

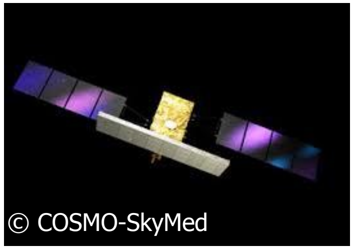
- **Investing ahead of others and converse**
  - Many nations now acquiring space-based capabilities
  - Commercial systems offering ISR services
  - Cubesats are good – low cost test platforms and capabilities
  - Cubesats are bad – low cost enable many to test & develop space capabilities that were cost prohibitive in the past
- **International collaboration**
  - US space S&T collaboration with allies and international partners continues to increase
- **Classifications**
  - US space S&T conducted at multiple security levels

S&T Opportunities

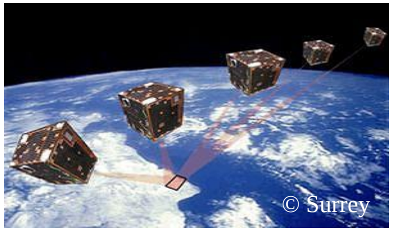
- **Exploiting expanding commercial space**
- **Ever growing and lucrative commercial satcom and ISR markets (GEO, MEO, and LEO)**
  - Digital Global Systems
  - TerraSAR-X
  - COSMO-SkyMed







- **Wealthy visionaries are investing in space tourism and transportation**
- **Commercial startups and international entrants are expanding micro and small sat capabilities**
  - Future large “micro” & “small sat” constellations
    - SpaceX –4,000 satellites
    - OneWeb – 2,400 satellites
    - Planet Labs – 128 satellites
    - SPIRE – 125 satellites
    - Black Sky - 60 satellites
    - Skybox – 24 satellites



- **NASA investments are buoying new entrants for orbital and suborbital markets**

Space Test Program
Recent Accomplishments

- **NRL Electrically-Controlled Solid Propulsion Experiment Low-Cost Demonstration and Qualification - Successfully deployed Dec 14**
- **AFRL Automated Navigation and Guidance Experiment for Local Space - Successfully launched in July 14**
- **Successfully launched in Nov 13:**
  - **AFRL Strip Sensor Unit**
  - **NRL Small Wind and Temperature Spectrometer**
  - **U.S. AF Academy Integrated Miniaturized Electrostatic Analyzer**
  - **NASA/NOAA Total Solar Irradiance Calibration Transfer Equipment**
  - **AFRL Joint Component Research**
  - **AFRL De-orbit Module**
  - **Cubesats from BlackKnight-1 (West Point)**
  - **Cubesats from Solar Cell Array Tester (Naval Postgraduate School)**
  - **NASA 13U Cubesats**
- **Two payloads on SpaceX Cassiope commercial mission via NASA - Successfully launched Sep 13:**
  - **AFRL Drag and Neutral Density Explorer (University of Colorado Boulder)**
  - **AFRL CUSat (Cornell)**

Army Space S&T Themes

Software Defined Radios

Low Size, Weight and Power, High Capacity, Flexible

Imagery

IR, Low Light, MSI

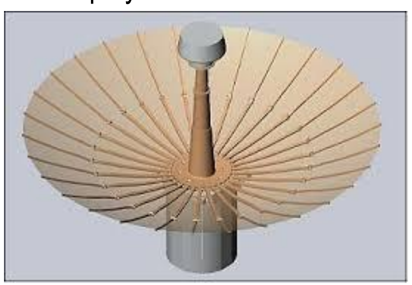
Satellite Down Link

Very High Data Rates

Encryption

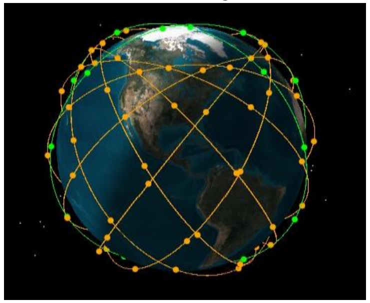
High Throughput

Deployable Antennas



Reliable, High Gain, CubeSat Compatible

Constellation Management



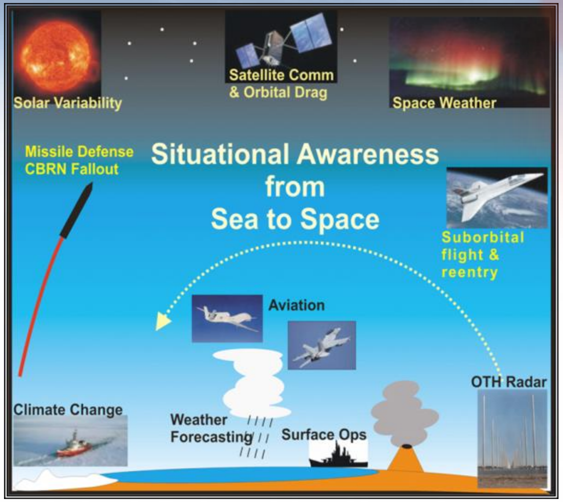
Highly automated, common architecture, optimized planning and tasking

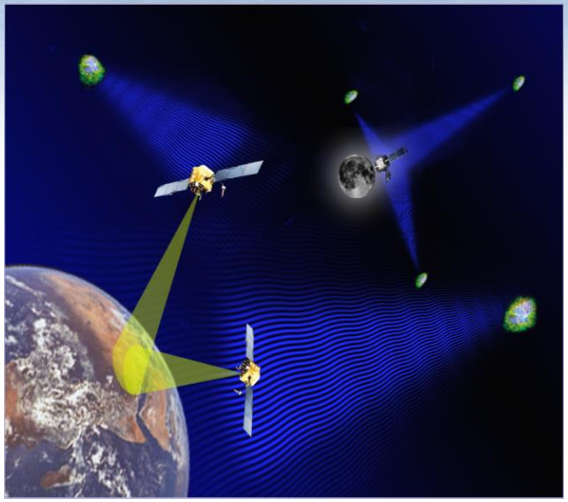
Tactical Launch

Low cost, responsive

Innovative, Affordable Space Technologies Support Future Battlefield Dominance

Navy Space S&T Themes - Research

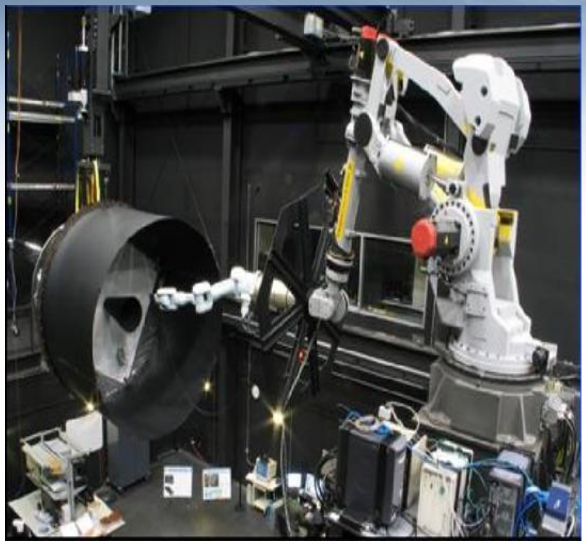


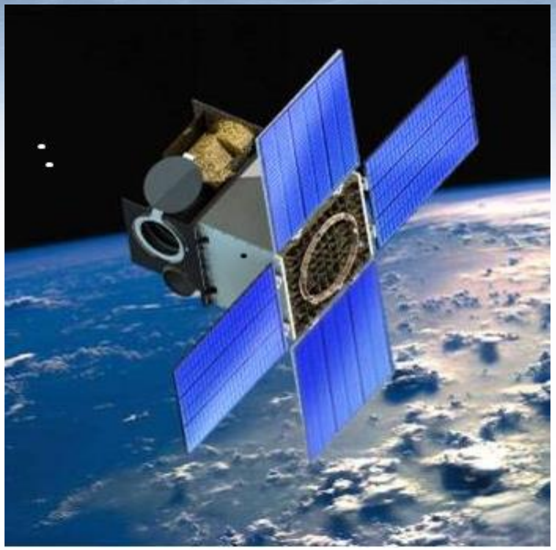


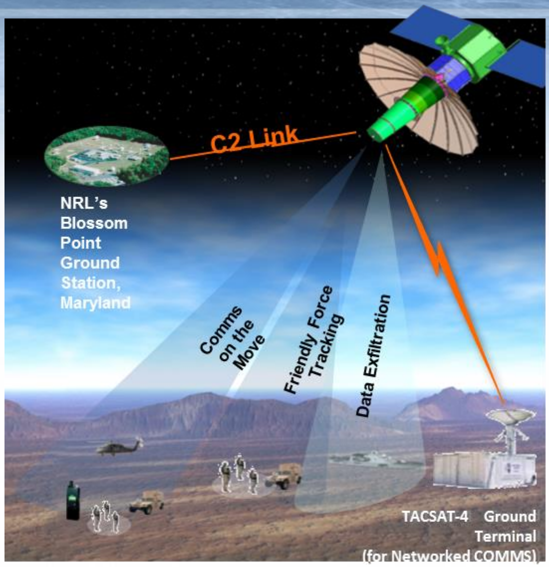
Geospace	Heliospace	High Energy Space
Observe and forecast, for enhanced situational awareness	**Develop improved sensors, specification, monitoring and prediction tools for operational impacts and real-time threat warning**	**Measure, simulate and model natural and artificial radiation and rad/nuke signatures, for detection and remediation**

Experimentally-led sensing R&D integrated across three environmental areas that underpin, connect, and inform successful operations, with metrics to increase TRL from 0-1 to 2 and to identify transition potential

Navy Space S&T Themes - Technology







Advanced Spacecraft Technologies

Sub-systems, for new and prototype building-blocks; propulsion & control, towards precision maneuvering while minimizing fuel; materials resiliency characterization

Payloads & Sensing

Next-generation, to improve monitoring for threats

Connectivity

High-bandwidth, space-based, for disadvantaged users

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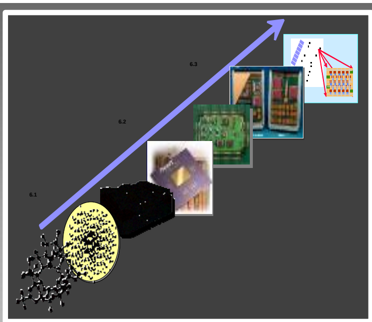
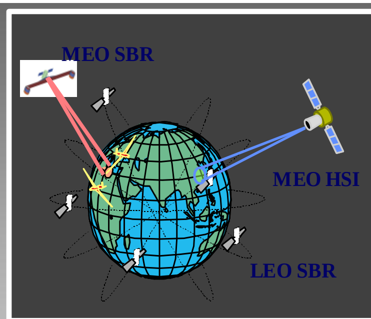
Air Force Space S&T Themes



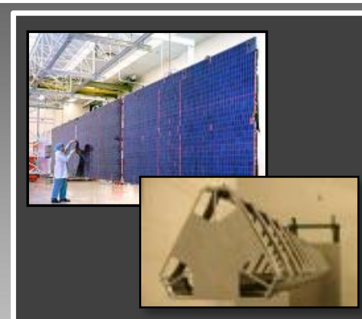
Space Electronics

- Space electronics physics to understand failure modes and improve reliability
- New space processors, solid-state amplifiers for GPS/Comm, A-D converters, memory



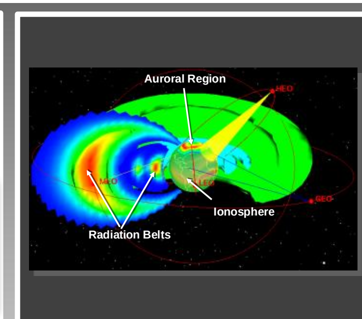
Space Remote Sensing

- Exploitation of collected photons (temporal, spectral, polarimetric)
- New sensors and components for missile warning
- Detectors, cryocoolers, algorithms, optics
- Nuclear explosion monitoring



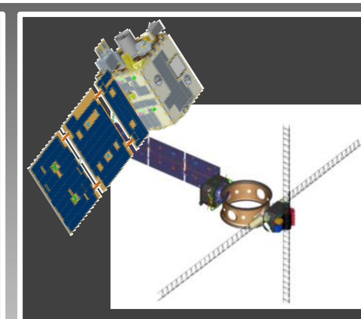
Space Platform & Ops Tech

- New technology to support AF-specific missions
- Solar arrays with 8X lower volume
- High-capacity thermal control
- Guidance, navigation
- Autonomous systems



Space Environment Impacts & Mitigation

- Models for spacecraft shielding and lifetime
- Anomaly resolution
- Astrodynamics for collision avoidance
- Reentry environment
- Space plasma physics & chemistry



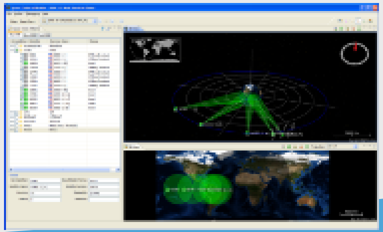
Space Flight Experiments

- Space system & payload development
- Integration, test, & flight
- Modeling & simulation
- Space system engineering

Air Force Space S&T Snapshot

Near Term

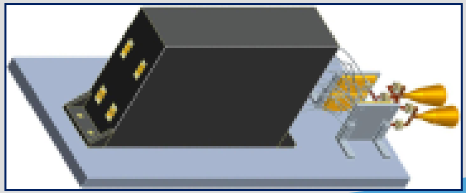
- SSA: Local GEO SSA using ANGELS spacecraft
- SSA: Resolved imaging of GEO from ground telescopes
  Protection: Space testing of new tech-insert options
- Comm: New thermal technology to increase WGS bandwidth by 25% (at Boeing)
- GPS: Higher transmit power to increase A2/AD jam resiliency
- JSpOC: Rapid all-on-all conjunction analysis



- WGS and Commercial Comm
- GPS III SV 9+
- JMS Increment 3

Mid Term

- SSA: Robust space Indications and Warnings for Battlespace management (BMC2)
- Protection: Autonomous Resilient spacecraft bus
- Comm: Increase frequency trade-space into the W/V band
- GPS: All-digital GPS payloads lowers cost, increases acquisition options, increases anti-jam
- Missile Warning: Detect difficult theater missiles under clouds



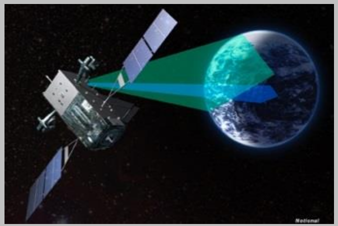
W/V payload (Ktr: NG)

- Protected Tactical Comm Service
- GPS – Next
- SBIRS and WFOV OPIR

Far Term

- Comm & GPS: Software agile systems for A2/AD
- Pervasive: e-Beam lithography for custom and trusted space electronics

Detecting difficult theater missiles under clouds

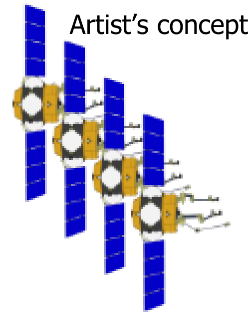


- AEHF Follow- On
- Staring OPIR for Battlespace Awareness

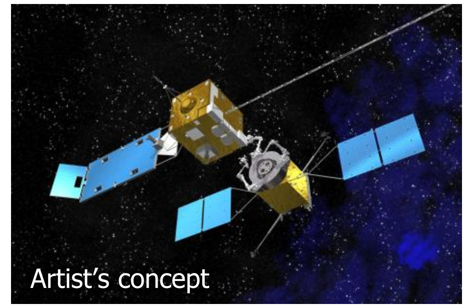
DARPA S&T Theme
GEO Servicing

SERVICING

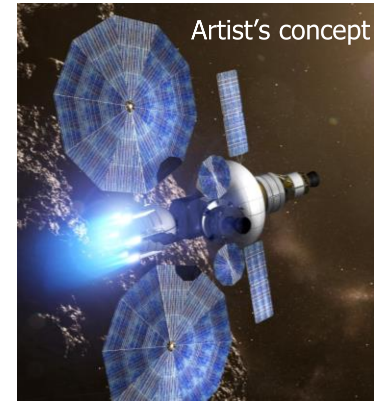
First robotic capability in GEO



Commercial providers expand coverage



Automated, scheduled refueling



LEO-to-GEO space tug

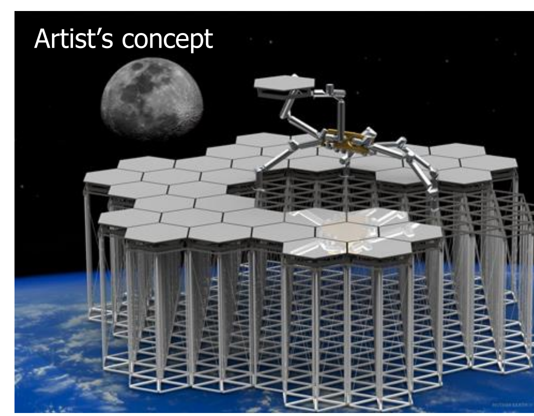
Technology development and investment

NEW ARCHITECTURES

- On-orbit replaceable units
  - Modular spacecraft

- Reduced redundancy
- Lightly fueled at launch
- Assembly experiments

Large apertures, structures and bases

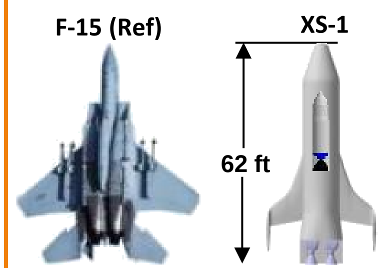


Space robotics = national-level growth potential

Responsive Launch Programs

Experimental Spaceplane (XS-1)

Approx Size Comparison



Gov't Reference Vehicle

Enable routine space access and testing of hypersonic aircraft technologies

PROGRAM OBJECTIVES

- Reusable 1st stage, expendable upper stage
- Fly XS-1 10 times in 10 days (no payload)
- Design for recurring cost 10X < Minotaur IV
  - > 3,000 lb payload
  - < $5M/flight
- Launch subscale orbital demo payload once

Airborne Launch Assist Space Access (ALASA)

Enable small satellites to be deployed to orbit from an airborne platform, allowing performance improvement, reducing range costs, and flying more frequently, which drives cost per launch down

PROGRAM OBJECTIVES

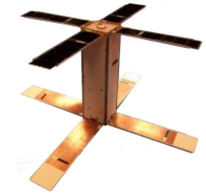
- Mature and demonstrate technologies for cost effective, routine, reliable access to low earth orbit (LEO) from airfields
- Reduce cost to $1M/flight in the 100 lb mass payload class
- Improve responsiveness to a 24-hour call-up to fit in the air tasking order cycle
- Deliver capability to launch into any Low Earth Orbit
- Demonstrate ability to disperse from a threatened launch airfield and execute mission from elsewhere

Army Program
Assured Communications

Operational/Technical Problem:

- Continued need for beyond line of sight (BLOS) communications for disadvantaged users in remote areas
- Exfiltration of ground sensors can result in soldiers exposing their data receive position
- Demand from one Combatant Command can limit another Combatant Command's communication access

Nanosatellites
10x10x34cm, 5.5 kg



Program Milestone Plan:

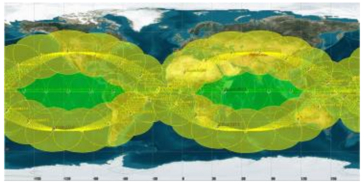
MILESTONES	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5
Non-recurring design & procurement					
Build of Nanosatellites					
Ground test					
Launch					
On orbit checkout and Tech Demo					
Operational Demo					
Joint Military Utility Assessment					

Technology Focus Areas:

System / Subsystem
Software Defined Radio
Propulsion
Encryption
Power Generation
High Gain Antenna
Ground Station

Enabling Technology Areas:

Constellation Management



Future potential: 3 orbital planes for near global coverage

Tactical Launch

Low cost, responsive

High data rate

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Army Program
On-Demand Small Satellite Imaging

Operational/Technical Problem:

Available Department of Defense & commercial imagery is insufficient to provide persistent Area of Responsibility surveillance, high priority to track targets. Imaging microsatellites could provide imagery data to support battlespace awareness, and battle damage assessment rapidly. Small, inexpensive satellites could be used in numbers to provide a persistent capability to the tactical warfighter.

Needs from On-Demand Imaging:

1. Tactical warfighters need situational awareness during combat ops
2. Ability to support persistence as an imaging source
3. Low production cost to support sufficient numbers of assets

On-Demand, small, imaging satellite program needs to determine mission areas, develop requirements, make design, build satellite(s), deploy, and demonstrate benefit via a Military Utility Assessment (MUA).

Infra-Red, Low Light, Multi-Spectral Imagery

Program Milestone Plan:

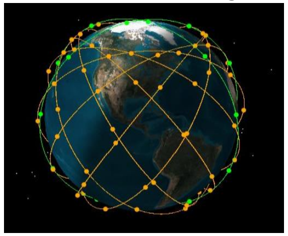
MILESTONES (THRUSTS)	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6
Satellite Concept & Design Develop	3			4		
Satellite Assembly & Integration						
Functional Testing				5		
Space Qualification						
Launch Integration & Deployment					6	
Intial Operations / Limited User Test					7	

Technology Focus Areas:

System / Subsystem
Image Resolution and Waveband
Pointing Accuracy
Image Down Link Rate
Structure Mechanisms
Ground Station
Propulsion
Production Cost

Enabling Technology Areas:

Constellation Management



Highly automated, common architecture, optimized planning and tasking

Tactical Launch

Low cost, responsive

Satellite Down Link

Very High Data Rates

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Navy Success Story WindSat/Coriolis

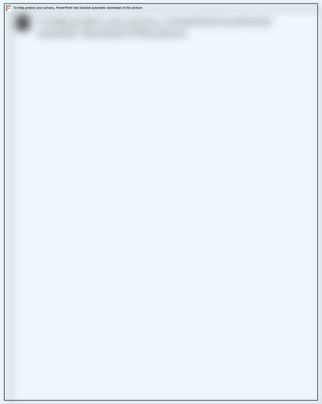
- **WindSat/Coriolis demonstrated the capability of polarimetric microwave radiometry to produce Ocean Surface Vector Winds (OSVW)**
  - Successfully operating for 12 years and counting
- **NRL provided the science, payload development, mission operations, vehicle integration, data product algorithms, and calibration/validation**
- **The only USA sensor providing global OSVW**
  - Also provides soil moisture, sea ice age/concentration, imagery for tropical cyclone intensity/tracking, snow depth
- **WindSat data are operationally assimilated into numerical weather models and used for other DoD and civilian applications**

Launched January 6, 2003

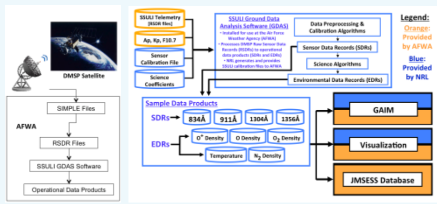
Navy Success Story
SSULI

SSULI: an advanced ionosphere remote sensing system that supports DoD operational needs

TRL 6-9



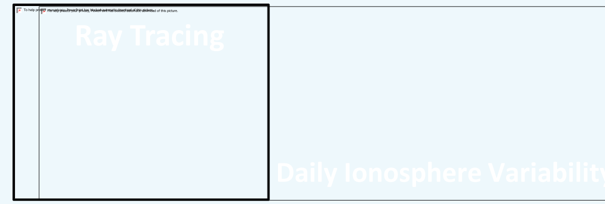
SSULI is DoD-operational aboard the DMSP F18, F19 satellites



NRL SSD software provides SSULI electron density products at the Air Force Weather Agency (AFWA)

2

TRL 1-2

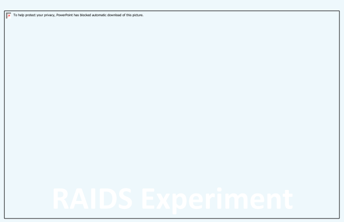


- *Ionosphere response to forcing and perturbations*
- *Next-generation optical techniques and sensors*
- *Operationally relevant models, measurements, and data products*

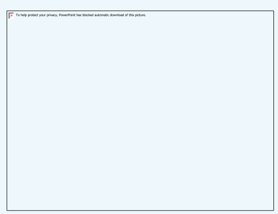
1

Concept for operational global EUV/FUV ionosphere/thermosphere monitoring

TRL 1-2



Innovative remote sensing space instrument development



Leading remote sensing data algorithms for space weather monitoring

SSULI sensors and data analysis algorithms grew from NRL research investment 1980-2006. Ongoing DMSP USAF sponsorship is enabling NRL to provide the SSULI sensors and processed SSULI data for operations

to higher TRL

Future: Next-gen ionospheric sensors for space weather science and myriad DoD applications

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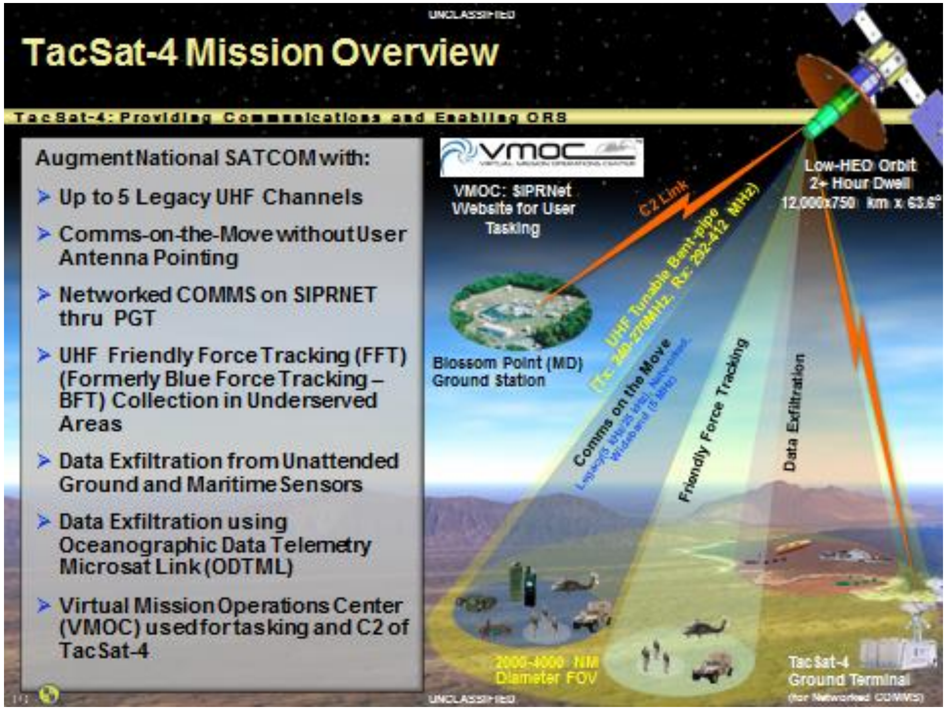
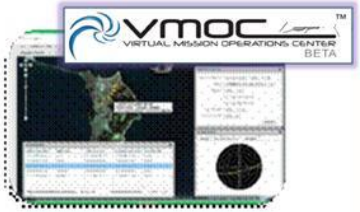
Navy Success Story
TacSat 4 & VMOC



- Space S&T COI met at NRL to review NRL's investment portfolio
- As a result of this COI interaction, Army SMDC leveraged current investment in NRL's Common Ground Architecture project Neptune and VMOC satellite C2 capability
- Army SMDC will realize an initial cost savings of approximately $450K per Ka Ground Station
- By sharing world-wide antenna resources with NRL's Blossom Point Tracking Facility, SMDC will avoid developing additional infrastructure which could cost up to $100M.

Cross-Service Leveraging Resulting from COI Interaction

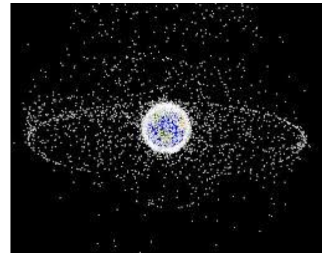
BP Command & Control and VMOC Mission Planning

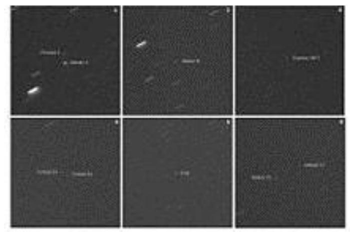


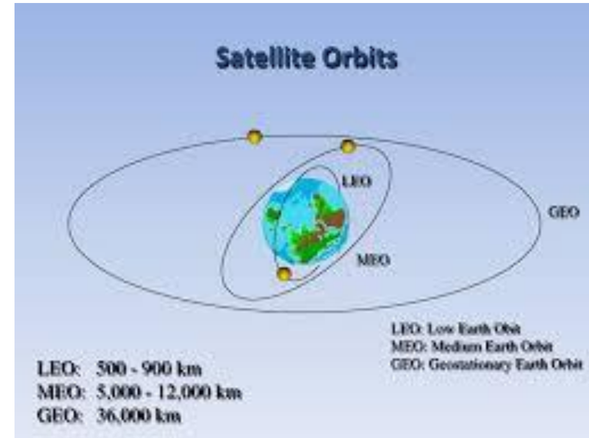
- State-of-the-Art capabilities & automation … working well

Air Force
GEO SSA Challenge

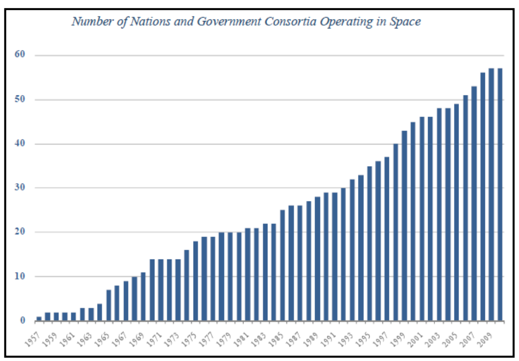
Critical SATCOM and Missile Warning DoD Assets at GEO

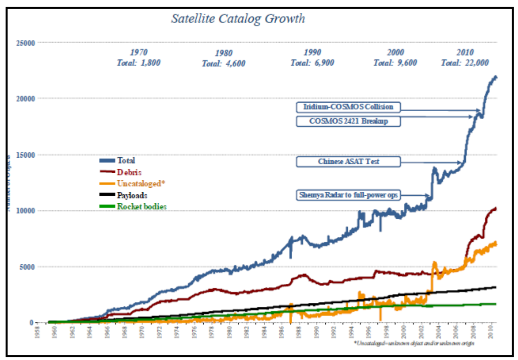






Sensing Challenge - GEO is 22,000 Miles from Earth





Number of Nations/Gov Consortia Operating in Space (Left) and Satellite Catalog Growth (Right) per US National Security Space Strategy (2011)

- DoD tracks >22,000 man-made objects in orbit
- Approximately 60 nations and gov consortia that own/operate satellites

Space is Becoming Increasingly Congested, Contested and Competitive.

Air Force Success Story

Roll-Out Solar Array (ROSA)
Revolutionary Solar Array Performance

Stowed

Deployed

Solar Cell Blanket

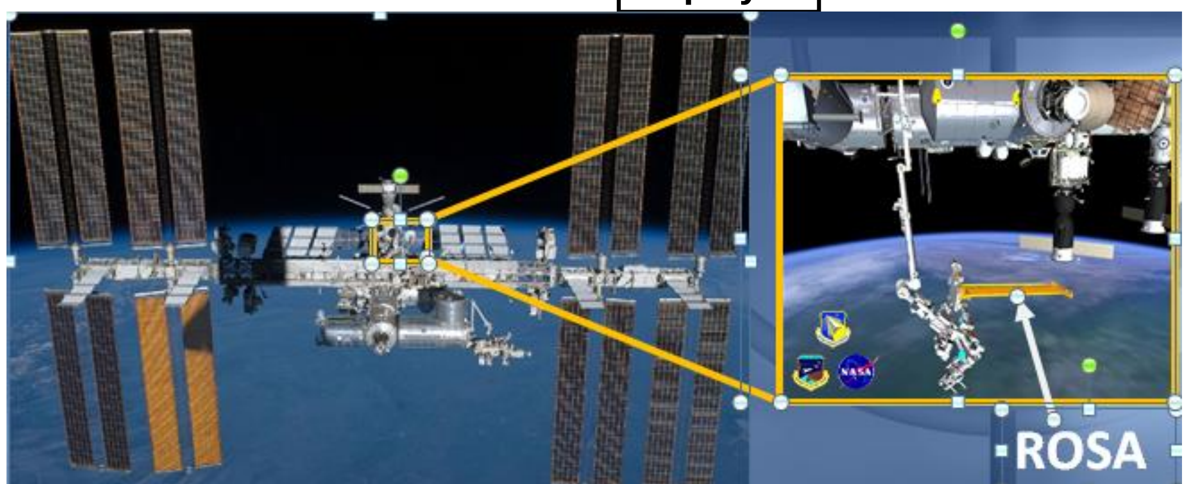
- Multiple solar cell types (rigid, flexible)
- Lightweight & high voltage capable
- Extremely thin and compliant package

Deployment and Support Structure

- Passively, elastically deployed array
- Lightweight, yet 4x stiffer than panels

Integrated Array

- Incredibly simple; 65% fewer fabrication drawings
- Very mass efficient
- Large deployed area from small stowed volume



ROSA flight experiment on the International Space Station; launch planned for August 2016

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Army
Future Space S&T Trends and Opportunities

- The Space Operational Environment will become increasingly complex over time (both in capacity and capability). Friendly, Coalition, and Threat forces will vie for Space capabilities and seek to deny others
- The future Army Operational Environment (Asymmetric warfare, Mega Cities, non-state operators, etc.) will be increasingly more dependent on tactical Space capabilities in multiple Mission Areas.

Navy Future Space Trends/ S&T Opportunities

- Multi-scale whole-atmosphere prediction of ionospheric effects, emphasis on Arctic and Tropical regions
- Terrestrial gamma-ray flashes observation base and background events modeling
- Characterize celestial pulsar sources for space-based GPS-stressed timing and navigation
- Investigate x-ray space-based communications
- Specification and prediction of geospace, heliospace, and high energy environmental effects for improved HF propagation, geolocation, SATCOM, orbital analysis, geomagnetic ULF resonance, and rad/nuke maritime detection and interdiction
- Imaging of GEO satellites from earth
- Cooperative, automatic space robotic capabilities
- Low-mass and novel active technologies for spacecraft propulsion systems
- Space sensor and analysis tools integrating on-orbit observations with modeling for improved SSA
- Lightweight articulation and sensing integrated space robotics architectures
- Spacecraft propulsion and control capabilities for precision maneuvering while minimizing fuel
- Low Earth Orbit radiation environment characterization payloads

Air Force Future Space S&T Trends

- **Space Comm:**
  - S&T to reduce risk on LEO constellation technology to support Air Dominance
  - Alternatives needed to AFSCN TT&C
- **Launch detection**
  - Near-term AFSPC/SMC focus is on low-cost disaggregation approaches.
  - Long-term DoD focus is on tactical missiles. AFRL Hyper-temporal is a major contribution, but gaps still exist.
- **PNT**
  - Resiliency needed for GPS space and control segments
  - PNT user equipment
- **SSA**
  - Leveraging commercial observations (ground and space) crucial to improve persistence
  - Key challenges are data trust, fusion, and interoperability with AF operational systems
  - Space-based, GEO focused SSA
- **Space Access**
  - Space Access
  - On orbit propulsion
- **Space C2 & Ops**
  - Leverage commercial systems.
- **Pervasives**
  - Protection and Resilience technology
  - S&T approaches to accelerate spacecraft manufacturing

DARPA Future Space S&T Trends

Launch:

- Flexible, affordable access
  - Affordable, routine and reliable access to space
  - Aircraft-like space access to lower cost and increase capabilities

Satellite:

- Changing the paradigm of satellite operations
  - New satellite architectures for speed and robustness
  - GEO space robotics to repair and assemble very large satellites that could not be launched

Space Domain Awareness (SDA):

- Real-time space domain awareness
  - Real-time detection and tracking versus catalog maintenance and days to weeks of forensics